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Molecular line emission from planet-forming Herbig Ae disks

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Abstract. We present ALMA observations of four different molecular species in showcasing their potential as tracers of physical and chemical conditions in planet forming Herbig Ae disks.

Keywords. astrochemistry, techniques: interferometric, (stars:) planetary systems: protoplanetary disks, stars: individual (HD 100546, HD 97048, HD 163296)

1. Introduction

Observations of protoplanetary disks with the Atacama Large Millimeter Array (ALMA) are revolutionizing our understanding disk structure and evolution. At millimetre wavelengths molecules, e.g. CO, HCO^+, HCN, SO, have bright detectable rotational transitions observable with ALMA. Molecular line observations of different tracers provide key information on the density, temperature and kinematics of the gas. We present ALMA observations of four different molecular tracers in three ringed disks around Herbig Ae stars.

2. ALMA Observations of Molecules in Herbig Ae Disks

2.1. *CO in the HD 163296 Disk*

Due to its high abundance relative to H_2 and relatively simple chemistry CO is used as the primary proxy for measuring the gas mass in disks (e.g. Bergin & Williams 2017). Most measurements use $^{13}C^{16}O$ and $^{12}C^{18}O$ isotopologues, but if this emission is optically thick the gas mass will be underestimated. In Booth *et al.* (2019a) we present the first detection of the rarest stable CO isotopologue $^{13}C^{17}O$ in a protoplanetary disk (see Figure 1a). We find the $^{12}C^{18}O$ emission is optically thick and the resulting disk gas mass is ≈ 2 to 6 times more massive than previous estimates using $^{12}C^{18}O$ (e.g. Isella *et al.* 2007; Williams & McPartland 2016).

2.2. *$H^{13}CO^+$ and $HC^{15}N$ in the HD 97048 Disk*

After CO, HCO+ and HCN are two of the brightest molecules detected in disks. Figure 1c and 1d show the integrated intensity maps of the new $H^{13}CO+$ and $HC^{15}N$ detections in the HD 97048 disk. The radial distributions of these tracers show hints of ringed sub-structure whereas, the optically thick tracers, CO and HCO+, do not. Additionally, our best by-eye fit models require radial variations in the $HCO+/H^{13}CO+$ abundance ratio and an overall enhancement in $H^{13}CO+$ relative to HCO+. This points to the presence of cold molecular gas in the outer disk (T <10 K, R > 200 au) (Booth *et al.* 2019b).

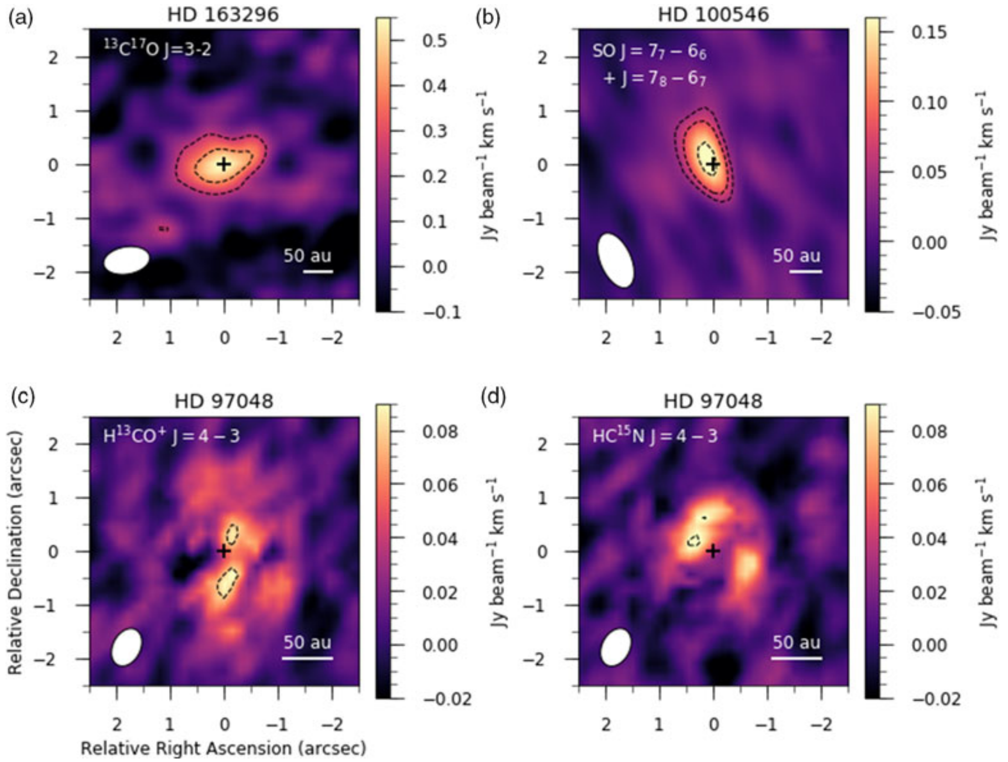

Figure 1. a) The $^{13}C^{17}O$ J=3-2 emission in the HD 163296 disk b) The stacked SO J $= 7_7 - 6_6$ and J $= 7_8 - 6_7$ lines in the HD 100546 disk c)-d) The $H^{13}CO^+$ and $HC^{15}N$ J=4−3 detections in the HD 97048 disk. The dashed black contours mark the 3, 5 and 10 σ levels where applicable.

2.3. *SO in the HD100546 Disk*

Sulphur-bearing volatiles are observed to be significantly depleted in disks (Dutrey *et al.* 2011). We have detected SO, a known shock tracer, in the HD 100546 disk for the first time (Booth *et al.* 2018). The emission is compact and asymmetric (see Figure 1b), and we have excess blue-shifted emission (-5 km/s). We postulate that the SO is tracing either a circum-planetary disk associated with the massive planet embedded in the disk at 50 au (Quanz *et al.* 2013) or, a disk wind.

3. Conclusion

This work showcases the power of molecular lines are tracers of the physical and chemical properties of disks around Herbig Ae stars. Future high spatial resolution observations, and chemical models that take into account the known dust (+gas) sub-structure in these disks, are needed to maximize their potential.

References

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